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ON DIFFERENTIAL MORTALITY WITH RESPECT TO SEED WEIGHT OCCURRING IN FIELD CULTURES OF PHASEOLUS VULGARIS

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INTRODUCTORY REMARKS

IN the rather voluminous literature of seed testing, comparatively little attention has been given to the possible relationship between the characteristics of the seed (or of the plant from which it was gathered) and its viability. This is of course attributable to the fact that such work has been done chiefly for immediately practical ends, the object being in most cases to determine, by germination tests of a small sample, the suitability of a given bulk of seed for commercial planting.

To the student of natural selection, however, the cardinal problem of viability is to determine whether the capacity for development of a seed is a function of its patent or potential (*i. e.*, of its own measurable or of its inherent but as yet undeveloped) characteristics. A satisfactory solution of this very complicated problem would, I believe, be of rather wide interest. At the outset, however, one must fix clearly in mind that if a selective mortality be demonstrated, it has no necessary bearing upon the question of the origin of species. Natural selection may maintain a type already differentiated as well as mould new forms but in order to do either the variations upon which it acts must be heritable. But in any case the results would be of interest to the physiologist concerned with the problems of the relationship between form and function. Finally, exact information on the relationship between structural characteristics and viability—if they exist—may be of some practical importance in agriculture and plant breeding.

The purpose of this paper is to present the first results of a series of studies on the relationship between the structural characteristics of the parent plant or of the seed itself and its viability. The data here recorded relate only to seed weight and are drawn from an extensive series of field plantings of carefully selected and individually weighed seeds of the common bean, *Phaseolus vulgaris*. They are properly described as a by-product, for the experiments were not carried out especially nor in the most satisfactory manner to test the existence of a selective mortality.

The conditions in field cultures of individually labelled seeds are such that many factors besides the weight of the seed are concerned in determining whether or not a seed shall develop into a mature plant. Some are lost by dashing rains separating seeds and labels, after which all questionable cases have to be thrown away. Some are destroyed by rodents and some by the unavoidable accidents of cultivation. In natural selection terminology, the non-selective death rate—the death rate which is no function of the characteristics of the individual—is very high. This tends to obscure the selective death rate, if such exists.

For just these reasons, I have never taken account of the characteristics of the seeds which failed to develop into mature plants, although the desirability of testing for the existence of a selective mortality for seed weight has been in mind almost from the beginning of the breeding experiments with garden beans in 1907. The records of those which developed to maturity were available for studies of heredity, influence of size of seed planted on characteristics of the plants produced, and so on. Data for the entire parental population from which the seeds planted were drawn were at hand for the study of the influences of season and environment. Under these circumstances, the only need for a record of the seeds which failed to develop to maturity would be for testing the hypothesis of the existence of a selective death rate. As suggested above, it seemed *a priori* improbable that a selective mortality could be detected in the large non-selective death rate of field cultures. But from an examination of the data which have accumulated during the last several years, it appears that the *a priori* scepticism which led to omitting records of the characteristics of the seeds failing to develop was unjustified. There appears to be, in fact, a selective mortality detectible by proper methods, even in field cultures.

The evidence upon which this statement is based is of the following kind. We know (*a*) the weight of all the seeds weighed in any year and (*b*) the weights of the sub-sample of seeds which developed into mature fertile plants in any subsequent year. Now the sample or samples which were planted were purely random drawings from the grand population forming the entire mass of seeds weighed for any culture. The physical constants for the distribution of weights of these sub-samples planted are, therefore, identical with those of the grand population, plus or minus the errors of random sampling. Ideally, to determine whether there be a differential mortality, we should compare the physical constants (means, standard deviations, and coefficients of variation) of the seeds which produced mature plants either with the constants of those of the same sub-samples which failed to do so or with the constants for the entire sub-sample planted. Practically, our end can be attained with reasonable exactness by comparing the constants of seeds which develop to maturity with those of the general population from which the plantings were drawn. The only objections to this procedure are two: (*a*) the results will be vitiated if the series of seeds planted are in any way selected, *i. e.*, not a purely random drawing from the general population, (*b*) the probable errors of random sampling in the drawing of the sample for planting are added to the probable errors of sampling due to the non-selective (purely random) death rate.

The first objection does not hold in the series discussed here, for I am confident that the plantings were true random samples of the general population of seeds weighed. With regard to the second, we note merely that its influence will make the detection of a selective mortality more difficult. If we find indications that the chances for development of a seed are conditioned by its weight we must therefore consider that the influence of weight is probably even stronger than is indicated by our evidence. Indeed, there might be a selective death rate scarcely detectible by the methods necessarily used in this study, but if these methods do indicate a selective elimination, we may have considerable confidence in its reality.

Studies of viability are generally limited to the capacity for forming a growing seedling, but there is no reason why tests should not be made more stringent by extending them to the capacity of the embryo for developing into a fertile plant. This has been done in these experiments.

Presentation of Data

The seriations of weights of seeds for the general populations are given in Table I; those for the sub-series of seeds which actually developed into fertile plants in Table II. The seriations for the grand populations are designated by the key letters of the crops of plants which produced them, those for the viable sub-samples by the key letters of the crops into which they developed.[1] The weights are recorded in units of .025 gram range; class 1 being 0–.025 gram, class 2, .025–.050 gram, etc. The constants are also expressed in terms of these units, but any one desiring to do so may easily transmute them into fractions of grams.

The biometric constants for the grand populations are given in Table III. Those for the sub-samples which actually produced fertile plants appear in Table IV.

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[1] These key letters are the same as those used in other papers published or in preparation. Hence, further information can be obtained by those who desire.

TABLE I

WEIGHT OF SEEDS FOR GENERAL POPULATION

Series	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	Totals
NH.....	2	2	14	87	361	1049	1507	1369	879	363	101	33	11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5778
NHH...	—	—	5	37	251	989	1963	2071	1253	489	172	69	24	8	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7334
NHD...	3	13	92	408	1037	1766	1732	995	417	119	37	8	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6630
ND.....	1	28	108	339	733	681	317	126	24	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2362
NDD...	—	13	32	118	371	663	632	366	130	33	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2362
NDH...	1	1	8	72	335	883	976	647	242	50	10	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3227
US.....	—	—	1	1	1	4	22	44	163	343	448	431	341	188	124	80	72	54	43	15	9	6	1	—	—	—	—	—	—	—	—	2391
USH....	—	—	1	1	2	—	2	23	90	165	219	212	161	103	59	52	40	13	18	3	—	1	—	—	—	—	—	—	—	—	—	1165
USD....	—	—	2	8	25	75	153	224	205	151	81	50	15	8	2	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1002
FS......	4	16	79	227	565	841	723	365	148	31	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3000
FSH....	1	1	12	52	262	742	698	275	61	16	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2122
FSD....	4	13	118	504	825	372	127	24	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1989
G......	—	—	—	—	—	—	—	1	2	1	6	14	18	21	49	55	53	73	115	129	102	79	85	61	52	26	21	19	7	7	1	997
GG.....	—	—	1	3	4	25	36	74	137	220	383	523	689	919	1073	1016	923	784	612	390	250	161	80	38	14	5	3	1	—	—	—	8364
GGH...	—	—	—	1	—	—	—	3	1	14	41	74	123	229	330	461	423	374	307	201	114	67	36	11	10	3	3	2	—	—	—	2828
GGD...	—	—	1	1	2	7	12	36	75	157	298	377	368	294	194	127	91	52	25	9	7	5	2	—	—	—	—	—	—	—	—	2140
L.......	—	1	5	8	15	32	38	81	96	144	217	336	339	401	305	304	232	184	69	28	15	9	1	1	—	—	—	—	—	—	—	2861

TABLE II

Weight of Seeds Producing Fertile Plants

Series	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	Totals
NHD......	1	—	3	18	89	276	386	298	211	95	28	8	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1416
NHH......	—	1	3	23	96	281	401	330	216	94	25	9	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1484
NHHH....	—	—	—	10	95	265	376	308	151	51	8	4	2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1271
NHDD....	2	3	14	80	230	319	285	157	80	25	6	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1204
NDH......	1	8	26	76	198	209	104	37	9	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	670
NDD......	—	3	25	53	143	151	87	42	8	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	513
NDDD....	—	2	4	15	44	124	147	87	27	6	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	459
NDHH....	1	—	1	13	42	160	164	130	42	9	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	565
US........	—	—	—	—	—	—	8	18	57	118	124	117	79	43	34	19	23	16	13	6	3	2	—	—	—	—	—	—	—	—	—	680
USH.......	—	—	—	—	1	1	1	10	27	43	73	56	61	28	15	12	11	8	11	1	1	1	—	—	—	—	—	—	—	—	—	361
USD.......	—	—	—	—	—	—	5	3	16	48	55	60	53	19	14	9	12	8	3	4	1	2	—	—	—	—	—	—	—	—	—	312
USC.......	—	1	1	1	—	2	4	5	27	62	92	109	70	60	28	21	19	16	8	2	2	—	—	—	—	—	—	—	—	—	—	530
USHH.....	—	—	—	—	—	—	—	5	20	26	43	49	36	26	8	6	4	1	—	—	—	—	—	—	—	—	—	—	—	—	—	224
USDD.....	—	—	—	2	5	13	31	49	61	34	22	14	5	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	237
FSS.......	—	6	21	72	170	241	194	118	36	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	868
FSH.......	—	2	9	43	80	116	131	64	24	5	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	475
FSD.......	2	3	10	25	78	138	102	43	20	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	428
FSC.......	1	1	15	40	98	168	154	72	31	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	586
FSHH.....	—	1	3	13	43	166	131	60	10	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	429
FSDD.....	1	2	10	79	166	84	36	8	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	387
GG........	—	—	—	—	—	—	—	1	1	1	3	9	14	17	36	44	37	57	82	96	81	63	64	54	43	18	16	13	4	4	1	759
GGH......	—	—	—	1	—	1	3	6	8	23	25	38	40	65	79	49	56	70	46	33	22	9	5	3	1	—	—	—	—	—	—	583
GGH$_2$......	—	—	—	—	—	2	6	2	9	8	19	37	53	56	76	56	56	50	31	19	8	5	2	2	1	1	—	—	—	—	—	499
GGD......	—	—	—	—	—	—	2	3	8	16	31	33	42	58	64	52	64	44	38	35	9	7	5	2	1	—	—	—	—	—	—	514
GGD$_2$......	—	—	—	—	—	1	—	4	8	12	24	28	39	41	64	59	65	35	31	17	10	8	1	2	—	—	—	—	—	—	—	449
GGHH.....	—	—	—	—	—	—	—	1	—	—	15	18	27	39	55	76	56	50	30	17	6	4	—	2	—	—	—	—	—	—	—	396
GGDD.....	—	—	—	—	1	1	2	3	5	16	38	49	61	57	45	24	21	11	5	1	2	—	—	—	—	—	—	—	—	—	—	342
LL........	—	—	—	—	—	—	16	35	37	66	95	132	135	169	128	123	85	74	18	—	5	1	—	—	—	—	—	—	—	—	—	1141

TABLE III

BIOMETRIC CONSTANTS FOR GENERAL POPULATION OF SEEDS WEIGHED

Series	Mean and Probable Error	Standard Deviation and Probable Error	Coefficient of Variation and Probable Error
NH	9.474 ± .013	1.490 ± .009	15.727 ± .101
NHH	9.774 ± .011	1.421 ± .008	14.537 ± .082
NHD	8.529 ± 012	1.458 ± .009	17.099 ± .103
ND	7.496 ± .018	1.310 ± .013	17.470 ± .182
NDD	8.487 ± .019	1.377 ± .014	16.218 ± .163
NDH	8.852 ± .015	1.555 ± .011	14.089 ± .121
US	14.297 ± .036	2.605 ± .025	18.218 ± .184
USH	14.204 ± .047	2.413 ± .034	16.987 ± .244
USD	10.690 ± .041	1.921 ± .029	17.972 ± .279
FS	8.229 ± .018	1.434 ± .013	17.427 ± .156
FSH	8.516 ± .016	1.092 ± .011	12.826 ± .135
FSD	6.956 ± .016	1.034 ± .011	14.858 ± .161
G	22.272 ± .081	3.796 ± .057	17.044 ± .265
GG	17.601 ± .024	3.264 ± .017	18.542 ± .100
GGH	18.919 ± .034	2.674 ± .024	14.131 ± .177
GGD	14.972 ± .036	2.498 ± .026	16.681 ± .193
L	15.667 ± .040	3.137 ± .028	20.023 ± .186

TABLE IV

BIOMETRIC CONSTANTS FOR SEEDS WHICH PRODUCED FERTILE PLANTS

Series	Mean and Probable Error	Standard Deviation and Probable Error	Coefficient of Variation and Probable Error
NHD	9.458 ± .027	1.507 ± .019	15.932 ± .207
NHH	9.445 ± .026	1.508 ± .019	15.962 ± .203
NHHH	9.275 ± .025	1.332 ± .018	14.356 ± .196
NHDD	8.459 ± .027	1.409 ± .019	16.657 ± .235
NDH	7.624 ± .033	1.283 ± .024	16.833 ± .319
NDD	7.733 ± .039	1.318 ± .028	17.049 ± .369
NDDD	8.756 ± .041	1.304 ± .029	14.892 ± .339
NDHH	8.929 ± .035	1.244 ± .025	13.930 ± .285
USS	14.143 ± .070	2.713 ± .050	19.180 ± .364
USH	14.330 ± .094	2.650 ± .067	18.495 ± .480
USD	14.394 ± .101	2.632 ± .071	18.283 ± .510
USC	14.496 ± .076	2.583 ± .054	17.819 ± .381
USHH	13.942 ± .087	1.927 ± .061	13.820 ± .449
USDD	10.852 ± .078	1.777 ± .055	16.371 ± .521
FSS	8.204 ± .033	1.434 ± .023	17.478 ± .292
FSH	8.326 ± .045	1.438 ± .032	17.276 ± .389
FSD	8.224 ± .047	1.430 ± .033	17.383 ± .413
FSC	8.312 ± .039	1.397 ± .028	16.809 ± .340
FSHH	8.483 ± .035	1.075 ± .025	12.668 ± .296
FSDD	7.194 ± .036	1.045 ± .025	14.520 ± .359
GG	22.324 ± .091	3.727 ± .065	16.695 ± .297
GGH	17.659 ± .094	3.359 ± .066	19.020 ± .389
GGH_2	17.305 ± .093	3.079 ± .066	17.792 ± .392
GGD	17.545 ± .095	3.188 ± .067	18.168 ± .395
GGD_2	17.448 ± .096	3.023 ± .068	17.327 ± .402
GGHH	18.038 ± .083	2.445 ± .059	13.555 ± .331
GGDD	15.515 ± .088	2.410 ± .062	15.536 ± .410
LL	15.524 ± .059	2.968 ± .042	19.121 ± .280

in all cases. Only the deviations of the sub-samples from the general population, *i. e.*, the differences obtained by Sheppard's correction was applied to the second moment subtracting constants for the general population from those for the sub-samples producing fertile plants, as given in Table V, require our attention.

Consider first the differences in mean seed weight.

They are equally divided between positive and negative, the average weight of the seeds which produced fertile plants being in 14 cases higher and in 14 cases lower than that of the general population of seeds from which the plantings were made. The average value of the positive differences is +.163 units; of the negative differences —.188 units; of the entire series of 28 comparisons

TABLE V

COMPARISON OF CONSTANTS FOR SEEDS PRODUCING FERTILE PLANTS WITH THOSE FOR THE GENERAL POPULATIONS WEIGHED

Series Compared	Mean and Probable Error	Standard Deviation and Probable Error	Coefficient of Variation and Probable Error
NHD–NH.......	−.016 ±.030	+.017 ±.021	+ .205 ±.230
NHH–NH.......	−.030 ±.030	+.018 ±.021	+ .235 ±.227
NHHH–NHH....	−.500 ±.028	−.089 ±.020	− .181 ±.212
NHDD–NHD....	−.070 ±.030	−.049 ±.021	− .442 ±.257
NDH–ND.......	+.128 ±.038	−.026 ±.027	− .637 ±.367
NDD–ND.......	+.237 ±.043	+.009 ±.031	− .421 ±.412
NDDD–NDD....	+.269 ±.045	−.073 ±.032	−1.326 ±.376
NDHH–NDH....	+.078 ±.038	−.312 ±.027	− .159 ±.310
USS–US.........	−.154 ±.025	+.108 ±.056	+ .962 ±.408
USH–US........	+.033 ±.101	+.046 ±.071	+ .277 ±.514
USD–US.........	+.098 ±.107	+.027 ±.076	+ .064 ±.542
USC–US.........	+.200 ±.084	−.021 ±.059	− .399 ±.423
USHH–USH.....	−.262 ±.099	−.486 ±.070	−3.167 ±.511
USDD–USD.....	+.163 ±.088	−.145 ±.062	−1.601 ±.591
FSS–FS.........	−.025 ±.037	−.000 ±.026	+ .051 ±.331
FSH–FS.........	+.098 ±.048	+.004 ±.034	− .151 ±.419
FSD–FS.........	−.004 ±.050	−.004 ±.035	− .044 ±.442
FSC–FS	+.084 ±.043	−.037 ±.030	− .618 ±.374
FSHH–FSH......	−.033 ±.039	−.018 ±.027	− .158 ±.325
FSDD–FSD......	+.238 ±.039	+.011 ±.028	− .338 ±.393
GG–G...........	+.052 ±.122	−.069 ±.086	− .349 ±.398
GGH–GG........	+.057 ±.097	+.095 ±.068	+ .478 ±.402
GGH$_2$–GG.......	−.297 ±.096	−.185 ±.068	− .750 ±.405
GGD–GG........	−.057 ±.098	−.076 ±.069	− .374 ±.407
GGD$_2$–GG.......	−.154 ±.099	−.240 ±.070	−1.215 ±.414
GGHH–GGH....	−.882 ±.089	−.228 ±.063	− .576 ±.375
GGDD–GGD....	+.542 ±.095	−.087 ±.067	−1.145 ±.453
LL–L...........	−.143 ±.071	−.168 ±.054	− .902 ±.336

—.012 units. Considering the differences individually in comparison with their probable errors[2] we note that if we regard a difference at least 2.50 times its probable error as statistically significant, 10 of the differences may be looked upon as trustworthy. Of these 5 are positive and 5 are negative. If we require $Diff./E_{diff.} = 4.00$, we find only 7 trustworthy cases, 4 positive and 3 negative in sign.

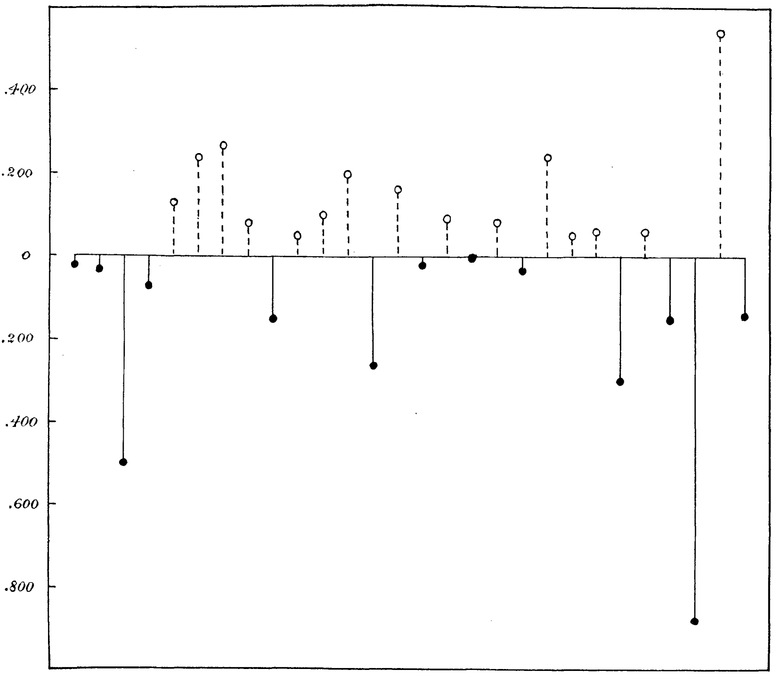

DIAGRAM I
Differences in Means.

Diagram I shows graphically the amount and the sign of the differences between the general and the viable samples. Here the different comparisons are shown from left to right in the order in which they are given from top to bottom in Table V. The distances of the solid dots below the zero bar indicate the amount of the negative deviations, the circles above the positive deviations.

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[2] It is somewhat difficult to decide just what ratio of the difference to its probable error should be used to indicate trustworthiness. As already emphasized, we have in reality two instead of one random sampling to take into consideration in the comparisons which we are drawing. The ratios $Diff./E_{diff.}$ are available to the reader who may assign to them any significance he sees fit. The general trend of the series furnishes much stronger evidence for a selective mortality than does the apparent statistical trustworthiness of any individual comparison.

From all of these considerations, we conclude that seeds which produce fertile plants are on the average neither lighter nor heavier than random samples of the population.

While the results for the means furnish no evidence for a selective mortality, the standard deviations are very suggestive of its existence. In 19 cases, the S.D. of the seeds which produce fertile plants is lower than that of the series from which they were drawn, while in 9 cases it is larger. The deviation from the equality to be expected if the differences were due purely to an infinite number of random sampling is therefore

$$5 \pm .67449 \sqrt{.5 \times .5 \times 28} = 5 \pm 1.79,$$

which is perhaps statistically significant. The chances against the result being due to the errors of sampling are roughly the same as those against 19 heads and 9 tails, or *vice versa*, in coin tossing.

Not only the inequality of the divisions of the signs into positive and negative, but the magnitude of the deviations themselves evidence for a selective mortality which reduces variability without sensibly affecting the average. The 9 positive deviations average $+.037$; the 19 negative $-.122$; the whole 28, $-.071$. The far greater magnitude of the negative deviations is made clear by the generally greater lengths of the bars below the zero line in diagram 2. Considering the individual differences in their relation to their probable errors, we note that in 7 cases the difference is over 2.5 times its probable error. *All of these are negative in sign.*

The coefficient of variation, that is, $100\sigma/m$, should show most clearly whether both larger and smaller seeds fail to develop, thus bringing about a reduction in variability which is independent of any change in the mean. The results given in the final column of the comparison table V, evidence even more strongly than the standard deviations in favor of such a selective elimination. They are lower for the seeds which develop into mature plants in 21 out of the 28 cases. This is a deviation from equality of

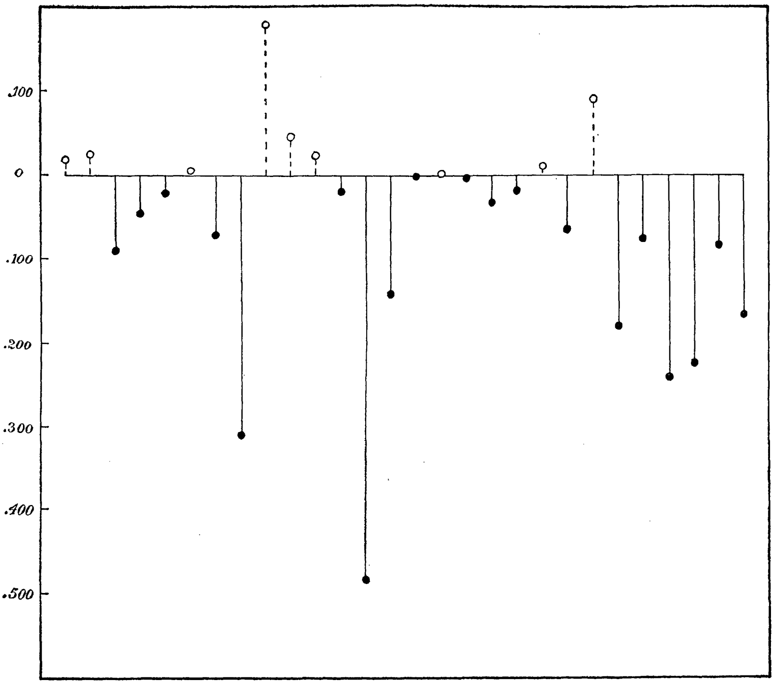

DIAGRAM II
Differences in Standard Deviations.

$$7 \pm .67449 \sqrt{.5 \times .5 \times 28} = 7 \pm 1.79.$$

The averages are:

For positive deviations,	+ .325
For negative deviations,	— .712
For all deviations,	— .453

Diagram 3 makes the reason for these differences clear to the eye. With regard to their probable errors, the six cases which are perhaps statistically significant, are all negative in sign.

SUMMARY AND DISCUSSION

Taken altogether the data seem to me to indicate a real differential mortality in seeds of *Phaseolus vulgaris* in field cultures. This selective death rate is of such a nature that the mean of the viable seeds remains practically the same as that of the original populations while their variability is reduced. In short, both large and small seeds are less capable of developing into fertile

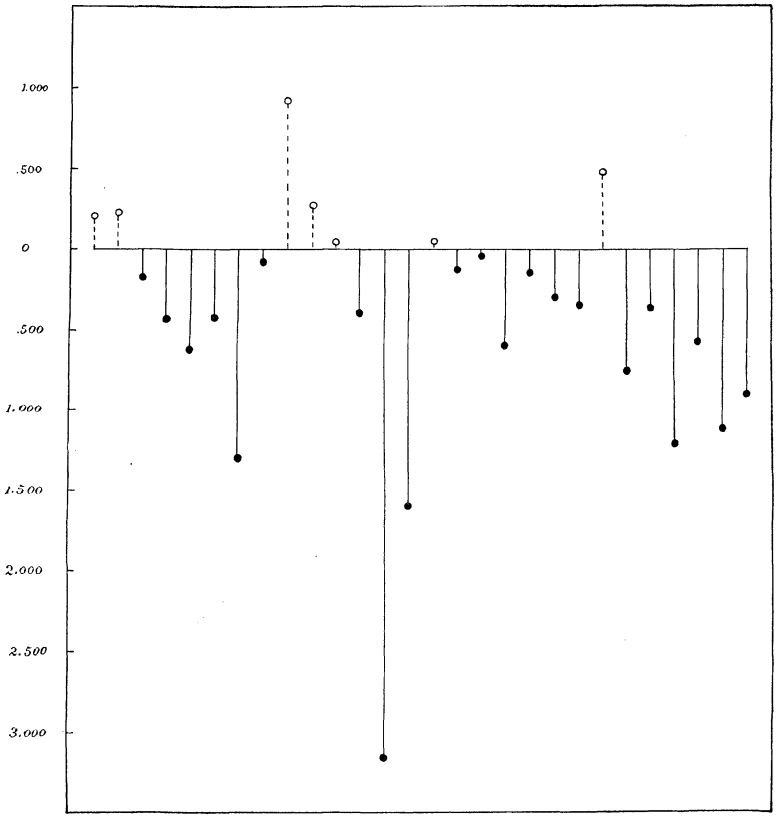

DIAGRAM III
Differences in Coefficients of Variation.

plants than are those which do not deviate so widely above or below the type.

While the evidences in support of these conclusions are fairly strong, it must not be forgotten that we are dealing with a problem of great delicacy upon materials grown under conditions such that the accidental (purely non-selective) death rate must be quite high, and with records not especially collected for our present purpose. Positiveness of assertion must therefore be reserved until more critical evidence collected *ad hoc* is available. The reader will note, however, that the conclusions here recorded are based on many thousands of observations. Although experiments are already under way, the gathering of the data necessary for a more thorough investigation of the problem will be a long task, and it seems only right that the results obtained incidentally should be placed on record for the benefit of those who may have opportunities for like observations.

To me personally, the results were surprising. First, I had doubted whether a selective mortality could be detected by the methods used. Second, I had supposed that if a differential viability were found, it would be limited to a weeding out of the lighter seeds. This latter presupposition was based on the fact that a positive correlation had already been demonstrated[3] between the weight of the seed planted and the number of pods produced, and *a priori* it seemed reasonable to suppose that viability and capacity for forming plants with large numbers of pods would bear the same relationship to the weight of the seed. Both questions deserve much more detailed and refined study.

Two questions concerning these results will be foremost in the mind of the biologist: (*a*) What is the significance of the selective elimination for evolution? (*b*) What are the underlying causes of the differential mortality?

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[3] Harris, J. Arthur, "On the Relationship between the Weight of the Seed Planted and the Characteristics of the Plant Produced," *Biometrika*, Vol. 9, No. 1, 1912.

The answer to (*a*) depends, as has been pointed out above, upon the inheritance or non-inheritance of the variations in seed weight. This question can not be discussed as yet, but from the data in hand, it seems to me likely that this selective elimination has little or no evolutionary significance. Certainly it is, as far as our evidence goes, not a cause of progressive change but only a factor tending to preserve an established type. It would then be an illustration of the "periodic selection" of Pearson.

The answer to (*b*) must be sought in the physiological, and of course ultimately, in the chemical and physical properties of the seeds of different weights. Experiments directed to its solution are under way.

COLD SPRING HARBOR, L. I.,
July 15, 1902